ULDB Systems Definition Review

Balloncraft Systems

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ULDB Balloncraft

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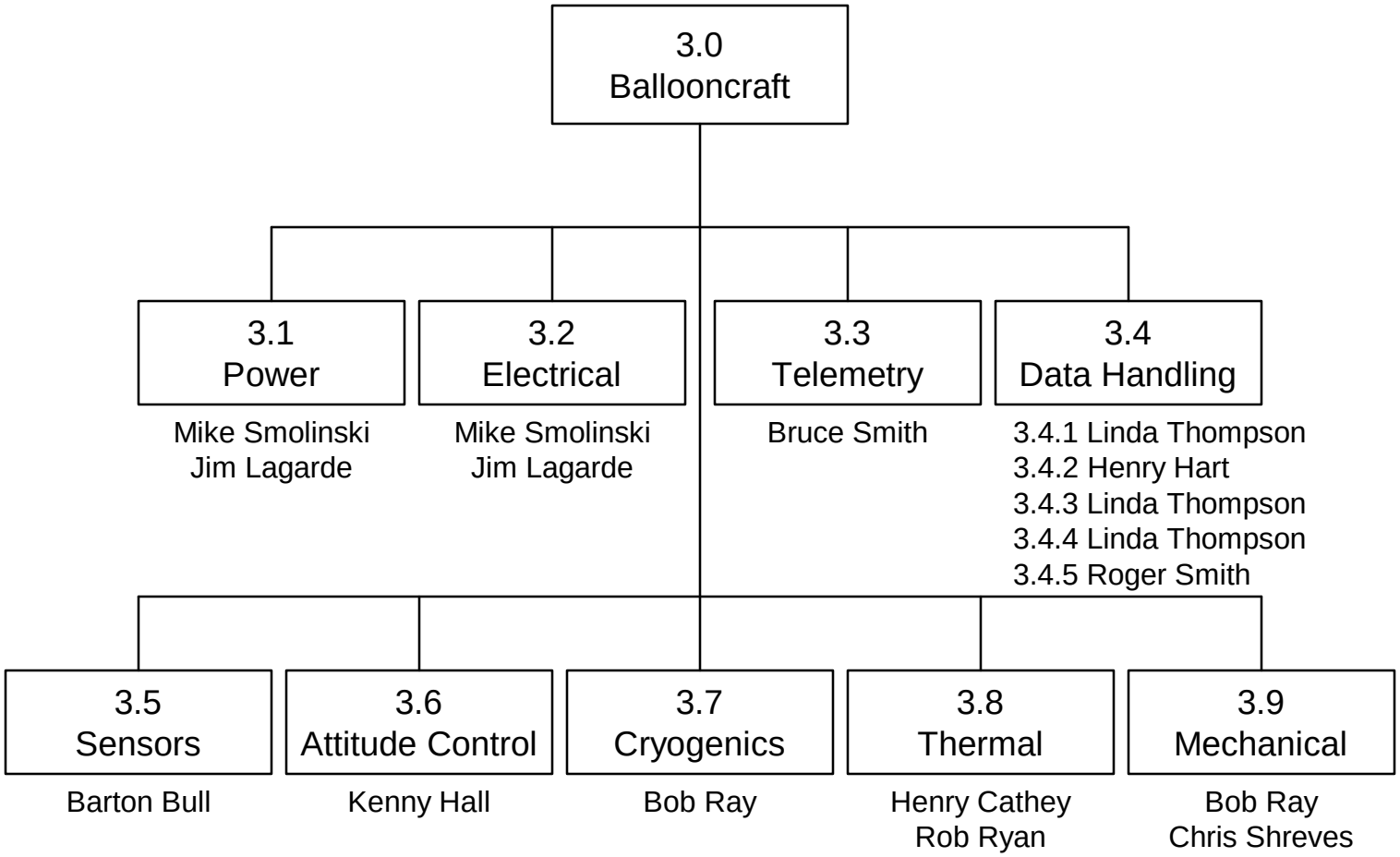
Balloncraft Design Study Team



Design Study Approach

- Requirements Definition
  - NASA HQ and GSFC Management
    - Policy and Directives
  - Science Support Requirements
    - Polidan Study, Demo 2000 instruments, Legacy
  - Design-to Requirements Document (DTRD)
- Design Concept Selection
  - Brainstorming Sessions, Market Surveys, Satellite Technology, Long Duration Balloon (LDB) systems
  - Trade Studies - feasibility and risk assessment
  - Optimum Subsystems Identified at SDR

3.1 Power Subsystem

- Objectives/Requirements
  - Scalable, mission specific subsystem, maximum 1000 watts (800 instrument, 200 support systems) based on 12 hour day/12 hour night, 28VDC +/- 4V
- Design Concepts Studied
  - POWER GENERATION
    - Solar Arrays (Positionable, Static, Deployable, Stowable), Radiometer Generator, Windmill, Nuclear / RTG's, Tether Through Magnetic Field, Fueled Generator, Uplink Microwave Energy, Stirling Engine
  - POWER STORAGE
    - Primary Batteries, Secondary Batteries, Capacitors, Flywheel, Fuel Cell

3.1 Power Subsystem

- Design Concept Selected
  - Deployable Solar Array Power
    - Modular Design, smaller array for lower power
    - Highest Power/Weight Ratio, low cost
    - Proven Reliability on Satellites and Balloons
  - Lithium Ion Battery Power Storage
    - Highest Power/Weight Ratio of batteries
    - Higher reliability than fuel cell
    - Reusable multiple flights
  - Risk Mitigation
    - Pursue preliminary design of regenerative fuel cell and battery storage options - decision at PDR
    - Existing Solar Panel/Silver-Zinc system maintained as contingency design

3.2 Electrical Subsystem

- Objectives/Requirements
  - Provide power distribution system to Control and Monitor the following:
    - Experiment power
    - Housekeeping
    - Pyro distribution circuit (Cutdown / Chute release)
    - Thermal management switching
    - Redundancy to allow for nominal recovery operations if Power System fails
  - Provide pyrotechnics and pyro actuator circuitry

3.2 Electrical Subsystem

- Design Concepts Studied
  - Modified LDB power distribution unit
  - Solid State Switching system
  - Laser Initiated Ordnance for Pyro circuits
  - Existing Pyrotechnics
- Design Concept Selected
  - Modified LDB power distribution unit
    - LDB system minimum weight, proven reliability
  - Laser Initiated Ordnance for Pyro circuits
    - laser initiators eliminate susceptibility of bridgewires to static discharge and induced current

3.3 Telecommunications Subsystem

- Objectives and Requirements
  - Provide Line of Sight (LOS) uplink command and downlink data
  - Provide global uplink command and downlink data
    - 50 kbps continuous average downlink rate
  - Provide primary and backup global uplink command subsystems for mission critical functions
- Design Concepts Studied
  - Military satellites, amateur satellites, TDRSS
  - Commercial Satellites
    - Iridium, Globalstar, OrbComm, ICO, Odyssey, Ellipso, Cyberstar, Celestri, Astrolink, Teledesic, Spaceway, Skybridge
  - LOS to Ground Stations, HF

3.3 Telecommunications Subsystem

- Design Concept Selected
  - Existing LOS systems
    - Exceeds current requirements
  - Balloon Class TDRSS transponder with pointed antenna and omni backup
    - TDRSS only global system with bit rate capability and schedule compatible with Demo 2000
  - Develop IRIDIUM system as secondary system
    - IRIDIUM in service 1998
- Risk Mitigation
  - Existing INMARSAT and ARGOS systems maintained as contingency designs

3.4.1 Data Acquisition Subsystem

- Objectives and Requirements
  - Provide a distributed subsystem that acquires data from sensors, subsystems, instruments
  - Analog & Digital inputs, event counters
  - Acquire data at Balloon Control Locations
- Design Concepts Studied
  - Acquisition
    - RS232, Essential Service Nodes (ESNs), LDB Stacks
  - Distribution Busses
    - AART, 1553A and B, 1773, Fiber Optics

3.4.1 Data Acquisition Subsystem

- Acquisition Design Concept Selected
  - PC104 based 232 card for 232 subsystems
    - 232 for legacy subsystems using mature COTS
  - LDB stacks for sensor and top plate acquisition
  - Universal Terminate Package (UTP) for terminate monitor and control
    - LDB stacks and UTP optimized for low weight and power, meet all requirements

3.4.1 Data Acquisition Subsystem

- Distribution Design Concept Selected
  - AART buss to LDB stacks
    - Flight proven reliability
  - 1553B bus to science flight computer(s)
    - 1553B allows redundancy of flight processors for instrument and instrument data, mature COTS
    - Allows future migration of other subsystems to 1553B
  - Fiber bus through balloon
    - Fiber will eliminate susceptibility of top plate communications to static discharge and induced current

3.4.2 Data Processing Subsystem

- Objectives and Requirements
  - Format instrument and mission data for transmission and on-board archive
  - Decode and validate uplink commands
  - Explore redundant architectures
- Design Concepts Studied
  - Form Factors
    - VME, PCI, PC-104, STD32
  - Space qualified processors
    - Mongoose V R3000, SwRI RAD 6000
  - Industrial grade COTS processors

3.4.2 Data Processing Subsystem

- Design Concept Selected
  - 486 class PC-104 bus core module
    - Compatible with RTOPS
    - Compatible with 1553B for redundancy
    - 100 times less cost than space qualified
    - Builds on proven LDB success with industrial grade SBCs
    - PC-104 small, low power, industrial grade, well supported, mature
    - Vendors with ruggedized BIOS, bootable solid state disk, F-16, 757 flight experience
    - Upgradable to 586 if necessary

3.4.3 Data Storage Subsystem

- Objectives and Requirements
  - Provide on-board storage of entire flight's data (50 kbps X 100 days = 54 GB)
  - Provide capability to replay data into downlink communications
- Design Concepts Studied
  - Solid State memory
  - Magnetic Tape Drives
  - Sealed Hard Disk Drives
  - DVD and/or CD optical read/write
  - Bubble memory
  - Flash memory

3.4.3 Data Storage Subsystem

- Design Concept Selected
  - PC104 Flash memory as buffer
    - Flash memory allows hard disk to be off until flash fills, then dump to hard disk
  - Hermetically sealed hard disks
    - Hard disks are flight proven, and will have adequate capacity with two disks
    - Most cost effective of alternatives

3.4.4 Command Subsystem

- Objectives and Requirements
  - Decode commands received from comm links
  - Forward commands to science flight computer(s)
  - Execute gondola and balloon control (distributed) commands
- Design Concepts Studied
  - Decode
    - Flight computer, firmware backup command decode, ESNs
  - Execute
    - LDB stacks, ESNs, PC104 I/O boards

3.4.4 Command Subsystem

- Design Concept Selected
  - Decode using the ULDB flight computers as prime and existing backup command decoder
  - Maintain UTP firmware command decoder and execute subsystems
  - Execute gondola commands using LDB stacks
    - Existing firmware decoders and LDB stacks optimized for low weight and power, flight proven, meet all requirements

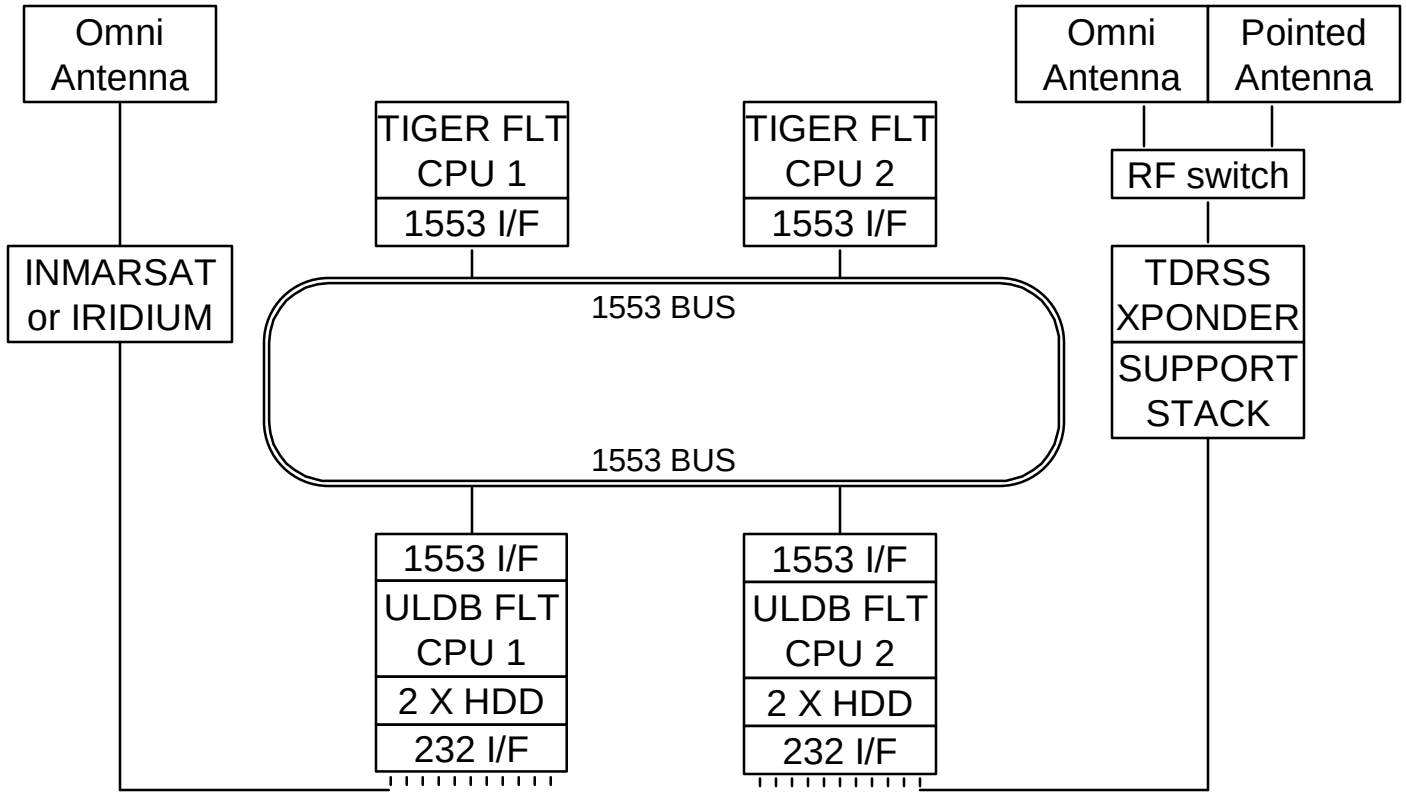
3.4.5 Flight Software Subsystem

- Objectives and Requirements
  - Acquire, process, format, archive, transmit and playback instrument data and mission data
- Design Concepts Studied
  - Contractor modification of existing flight software
  - In-house modification of existing flight software
  - In-house RTOPS custom software for commercial hardware
  - In-house RTOPS custom software for custom hardware
  - In-house modification of commercial RTOPS software for commercial hardware

3.4.5 Flight Software Subsystem

- Design Concept Selected
  - In-house modification of commercial RTOPS software for commercial hardware
    - COTS RTOPS offers efficiency/compactness versus existing DOS
    - Development in C, C++ familiar to WFF developers versus ADA used in existing flight software
    - COTS drivers, RTOPS reduces development time and risk
    - Allows in-house control of development and maintenance versus contractor modified code
    - Eliminates learning curves associated with WFF modification of existing software

CPU-Comm-1553 Architecture



232 PORTS		
	1.LOS xmttr (PCM)	6.Acq & Cmd Stacks
	2.LOS rcvr (cmd)	7.ARGOS PTT
	3.Rotator	8.ULDB Vehicle
	4.Ground Diagnostics	9.GPS
	5.Balloon Control	10.Comm Subsystem

3.5 Sensors Subsystem

- Objectives and Requirements
  - Provide position, velocity, timing sensors
  - Provide sensors for engineering and housekeeping measurements
- Design Concepts Studied
  - Position and Velocity
    - LORAN, OMEGA, Radar/Optical tracking, satellite positioning
  - Other housekeeping and engineering measurements
    - Existing versus new transducers

3.5 Sensors Subsystem

- Design Concept Selected
  - GPS for position, velocity, timing
    - GPS flight proven, low cost/power/volume
  - Pressure transducer(s) for pressure altitude
    - Pressure measurement needed for vehicle, instruments
  - Mixture of existing and new sensors for other requirements
    - New sensors recommended where smaller, lighter, less expensive and/or higher performance than existing

3.6 Attitude Control Subsystem

- Objectives and Requirements
  - Provide Gondola Azimuth Control
    - Three instrument pointing modes - spin, scan, point relative to sun/moon/true north
    - Sun tracking mode for power system pointing
    - Rate accuracy 20 percent
    - Pointing accuracy one degree (peak)
    - Azimuth determination one degree (peak)
- Design Concepts Studied
  - Enhanced WFF/LDB pointer
  - Joint ventures with existing science team provided pointers
  - New design

3.6 Attitude Control Subsystem

- Design Concept Selected
  - Modified WFF/LDB rotator
    - Flight proven
    - Capable of meeting higher accuracy and extra modes with less FTEs than new system
    - Sun tracking mode uses less power (<5 watts) than science team developed pointers
    - Designed and built in-house

3.7 Cryogenics Subsystem

- Objectives/Requirements
  - An electro-mechanical device capable of cooling science instruments.
  - Target performance - capable of cooling 4 watt heat load to 80 Kelvin with a heat reject of 40 C.
  - Affordable, light weight, low power demand.
- Cryogenic Coolers Studied
  - Sunpower Model M77 Stirling Cycle Cooler
  - Hughes SSC Sterling Stirling Cycle Cooler
  - Ball SA160 Stirling Cycle Cooler
  - TRW 60 Kelvin Unit Pulse Tube

3.7 Cryogenics Subsystem

- Design Concept Selected
  - Sunpower Model M77 Stirling Cycle Cooler
    - Sunpower is <$50,000 all others >$1,000,000.
    - GSFC/Greenbelt has tested this unit and developed vibration dampening circuitry
- Development Status
  - Sunpower Cryocooler test flight June 1998 on LDB flight from Alaska
  - WFF in-house housing, thermal control system, vibration monitoring system
  - Code 713 in-house vibration dampening
  - On schedule for integration and test at NSBF in April

3.8 Thermal Subsystem

- Objectives and Requirements
  - Provide thermal control systems to maintain subsystems and components within their specified operating temperature ranges
- Design Concepts Studied
  - Passive (non-power consuming) Control Methods
    - surface finishes, coatings, insulation, louvers, etc.
  - Active (power consuming) Control Methods
    - Heaters, mechanical coolers,
  - Control via deployment, mechanisms, thermal storage, heat exchange, heat transport, expendable, control from external sources

3.8 Thermal Subsystem

- Design Concept Selected
  - Primary approach - passive techniques
    - reliable, light weight, no power, low complexity/cost
    - surface finishes, coatings, insulated enclosures
  - Apply next level of complexity as required
    - louvers - no power but mechanisms, pointed required
    - Resistive heaters - spot use, power required, reliable
    - Radiators - weight penalty, more complex thermal path, pointing required

3.9 Mechanical Subsystem

- Objectives and Requirements
  - Gondola fabrication
  - Support design and fabrication of other subsystem requiring mechanical devices (pointed TDRSS ant)
- Design Concepts Studied
  - Gondola construction materials and techniques
    - aluminum angle, aluminum tubing, graphite composite, foam filled/sandwiched aluminum
  - TDRSS antenna positioner
    - Modify COTS non-flight qualified hardware
    - New in-house design

3.9 Mechanical Subsystem

- Design Concept Selected
  - Gondola fabrication material
    - Aluminum Angle - short development schedule, low risk, low cost
  - TDRSS antenna positioner
    - In-house design - no COTS positioner found without high risk modifications required
    - COTS market survey will continue until PDR

4.4 Ground Monitor and Control Subsystem

- Objectives and Requirements
  - Provide Operations Control Center (OCC)
  - Provide Remote Operations Control Center (ROCC)
  - Provide portable system for terminate/recovery
    - All provide conversion of received data into engineering units, display of data, archive of data
    - All provide initiation of commands for transmission
    - OCC provides capability for remote instrument provider to retrieve data in near real-time and submit commands via TCP/IP

4.4 Ground Monitor and Control Subsystem

- Design Concepts Studied
  - Platforms - PC, Workstation
  - Operating Systems - NT, UNIX
  - Telemetry Data Handler - PTP, TDPlus, TSI TelSys
  - Data Processing and Display
    - PV-Wave, Quinn-Curtis real-time graphics tools
  - Data Management and Storage
    - WFF Standard Autonomous File Server (SAFS)
  - Monitor and Control Process
    - LabView, WFF Automated Tracking Station MCS

4.4 Ground Monitor and Control Subsystem

- Design Concept Selected
  - PC Platform with Windows NT
    - Low cost, portable, mature, reliable
  - PTP Telemetry Data Handler
    - Highest feasibility, lowest risk
  - PV-Wave Data Processing and Display
    - Industry standard, less development than alternative
  - SAFS Data Management and Storage
    - Under development in-house for Ground Stations, meets all requirements
  - LabView Monitor and Control Process
    - Industry standard, COTS, mature, reliable

Comparison ULDB - LDB

Requirements/Subsystems Commonality

- Communication Systems
  - Prime/backup global data and command systems
  - Line of Sight requirements
- Low power distributed data acquisition and command execute system
- Processing functional requirements
- Positioning (location) requirements
- Basic OCC and ROCC requirements
- Redundant support system power
- Redundant flight critical subsystems

Comparison ULDB - LDB

ULDB Enhancements

- Reduce Volume and Weight
  - Change from separate fixed mechanical package to modular system integrated with instrument(s) in single gondola design
- Power
  - Integrated subsystem for instrument and support
  - Power storage for up to 12 hour night
- Higher accuracy pointing subsystem
- Balloon wiring and pyrotechnics less susceptible to static discharge, RFI, EMI
- Increased global downlink data rate to 50kbps, increased on-board archive
- Provide new capabilities
  - IRIDIUM, cryocooler, 1553 bus

Backup Slide - 3.1 Power

- Regenerative Fuel Cell
  - Closed Cycle System
    - Solar Panels used to electrolize water during day into H and O, which powers fuel cell at night
    - Highest Power/Weight Ratio
    - Reusable - minimal refurbishment costs
    - Development Proposal from Lewis Research Center

Backup Slide - 3.1 Power

Item	Volume	Mass
Solar Array (2kw)	300 sq. ft.	100 lbs.
Electronics	1.5 cu. ft.	20 lbs.
Power Storage Options (12,000 watt-hours)		
Lithium Ion batteries	7 cu. ft.	305 lbs.
Silver Zinc batteries	7.5 cu. ft.	600 lbs.
NiMH batteries	8 cu. ft.	680 lbs.
Fuel Cell	12 cu. ft.	140 lbs.

Backup Slide - 3.3 Telecommunications

- Commercial Satellite Communication Systems
  - IRIDIUM
    - 52 of 66 satellites launched, 49 operational
    - 2400 bps, 1.616 - 1.6265 MHz
    - service start 4th quarter CY98
    - DOD has own gateway in Hawaii, US Army will field test 300 units in Korea this summer
    - Motorola handset 1 lb. 0.645 watt 25 cu. in. with 232 port
  - GLOBALSTAR
    - 4 of 56 satellites launched
    - 9600 bps
    - service start 2nd quarter CY99
  - ORBCOMM
    - 12 of 36 satellites launched
    - 2400 bps uplink, 4800 bps downlink
    - limited coverage now, service start 2nd quarter CY99

Backup Slide
Universal Terminate Package

- Developed by PSL and NSBF for use on all balloon flights
  - Redundant UHF command receivers
  - Redundant EPLD command decoders
  - Redundant relay control
  - Remote Firing Unit with redundant Capacitive Discharge Pyrotechnics for terminate
  - AART bus for data and command to/from LDB SIP
  - Helium Valve (Top Plate) monitor and control
  - Parachute Release monitor and control
  - Critical Design Review February 1997, qualification flight in Fall 1998

Backup Slide
LDB/ULDB Subsystem Comparison

LDB SUBSYSTEMS	ULDB SUBSYSTEMS	PPP	PPC
LDB Power	ULDB Power		
Omni PV array	Pointed PV array		
2 Charge Controllers	New modular Charge Controllers		X
Silver Zinc Batteries	Lithium Ion Batteries		X
LDB Electrical	ULDB Electrical		
Power Distribution Unit	same		
LDB Communications	ULDB Communications		
INMARSAT	IRIDIUM or INMARSAT	X	
TDRSS/omni antenna	TDRSS/pointed antenna		X
dual LOS UHF rcvrs	same	X	
dual LOS xmttrs	same		
ARGOS PTTs	same	X	
LDB C&DH	ULDB C&DH		
Citadel flight computer	new flight computer	X	
Hard Disk	same type, higher density HDD		
system stack	same		
power stack	same		
serial isolator	same		
LDB DOS flight software	new RTOPS flight software	X	
LOS PCM encoder	same		X
232/AART distribution	232/AART and 1553 distribution	X	

Backup Slide
LDB/ULDB Subsystem Comparison

LDB SUBSYSTEMS	ULDB SUBSYSTEMS	PPP	PPC
LDB Sensors	ULDB Sensors		
GPS	new GPS		X
MKS Pressure Sensors	same		
Housekeeping	some new		
LDB Attitude Control	ULDB Attitude Control		
WFF developed rotator	Enhanced WFF rotator		
LDB Cryogenics	ULDB Cryogenics		
No systems	Stirling Cycle Cryocooler	X	
LDB Thermal	ULDB Thermal		
SIP enclosure	Modular, integrated enclosures		
surface coatings	surface coatings, new as required		
spot heaters	spot heaters		
LDB Mechanical	ULDB Mechanical		
SIP structure	Integrated structure		
Backup NAV CPU/GPS/ARGOS	No backup NAV		
Universal Terminate Package	Universal Terminate Package		
Capacitive Discharge Pyro	Laser initiated pyro	X	
Twisted pair through balloon	Fiber Optics through balloon	X	
LDB top stack on top plate	same		